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ABSTRACT

Two field trials were conducted to test the effectiveness of instructional materials, which were presented on an Apple II Plus microcomputer interfaced with a videocassette recorder, in teaching mathematical skills to students who had not made normal progress in mathematics learning. In the first field trial, 58 experimental students from a high school with a high proportion of Hispanic students participated in modules covering instruction in factors and prime numbers. A criterion-referenced pre- and posttest and a School Learning Questionnaire (SLQ) were administered to both the experimental students and to 43 control students. A second field trial retested the factors and prime numbers modules and provided a pilot test of a fractions module. The subjects were 11 volunteers from an alternative school remedial program for students who had failed to pass the basic skills competency test required for high school graduation. Pre- and posttests were again administered. The results of the field trials showed that the computer-video instructional modules were effective in teaching or reteaching mathematical skills to secondary school students. However, the hypothesis that exposure to the instructional materials would be reflected in an increase in effort attributions specific to mathematics was not supported. A 38-item bibliography accompanies this report. (ESR)

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EFFECTS OF INTERACTIVE VIDEO/COMPUTER INSTRUCTION ON THE PERFORMANCE OF UNDERACHIEVING STUDENTS IN MATHEMATICS[1]

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EFFECTS OF INTERACTIVE VIDEO/COMPUTER INSTRUCTION ON THE PERFORMANCE OF UNDERACHIEVING STUDENTS IN MATHEMATICS

A growing awareness of the status of mathematics and science education in the United States has generated a pervasive sense of concern among educators and concerned citizens alike. This distress is based on a variety of different forms of evidence that mathematics and science achievement is declining among American secondary school and college students. For example, mathematics scores on college entrance examinations have dropped steadily for the past 20 years (National Academy of Sciences, and National Academy of Engineering 1982).

Within the context of this general problem, particular concern has been voiced regarding the special plight of female and minority students, both of whom tend to be underrepresented in the high school mathematics tracks that lead to career opportunities in scientific and technical fields. A recent survey (Sells, 1979) indicated that fewer than half as many women as men first year students at the University of California, Berkeley, had sufficient high school preparation in mathematics to enter the calculus sequence which is so critical to studies leading to careers in scientific and technical fields. Even though their participation in mathematics courses is relatively low, increasing numbers of women are shifting their career interests away from traditional female careers, expressing instead interest in science and in technical fields (Magarrell, 1980). Similarly, minority students are grossly underrepresented in advanced mathematics courses in high school (Sells, 1979, 1980), effectively

eliminating a large spectrum of educational and career choices.

Clearly there is a need to reverse this trend of declining achievement in mathematics, and to accomplish this in ways that can afford women and minority students the opportunity to participate more fully in scientific and technical careers. The problems involved in responding to this challenge are exacerbated by a severe shortage of teachers in mathematics and science, and by general declines in appropriations for education. Reductions in state and local funding for education in California, for example, have resulted in larger classes and corresponding restrictions on the amount of time teachers can spend with individual students who encounter difficulties.

Research along several lines is needed to address the educational and social problems presented by this situation. One approach involves basic research on the underlying causes of group differences in mathematics achievement and participation. While this research on socialization and other antecedent conditions is of critical importance, it is also essential to develop immediate and effective means by which students now in school might be helped. The application of educational technology has been suggested as one approach to this problem. The feasibility research reported in the present study falls within this category. The general goal of this research was to develop and test the efficacy of an approach employing educational technology as an adjunct to classroom instruction.

There is an abundance of evidence that computers may provide an effective means of improving performance in a variety of subjects, including mathematics. A number of reviews of research on computer based instruction (Jamison, Suppes, & Wells, 1974; Kearsley, Hunter, & Seidel, 1983; Vinsonhaler & Bass, 1972) and meta-analyses of the research literature (Burns & Bozeman, 1981; Hartley, 1977; Kulik, Bangert, & Williams, 1983) have shown quite consistent positive effects on both achievement and attitudes. A number of these positive effects have been specific to mathematics education (Burns & Bozeman, 1981; Hartley, 1977).

There is also a large body of evidence that television can serve as an effective instructional medium for teaching students from preschool through college in a variety of subject areas (Chu & Schramm, 1967).

The inherent limitations of both instructional television and computers may be overcome by coupling the power and interactive properties of the computer and the unique properties of television through the use of an interface than makes it possible for a microcomputer to control the presentation of video taped explanations, demonstrations, and modeling of problem solving strategies. These capabilities are most effectively attained by interfacing the computer with the display features and high density storage capacity of the videodisk (Molnar, 1982). Although the intelligent-videodisk may ultimately be the most effective way to combine the unique instructional features of both

television and the computer, this technology is not yet generally available in the schools, and its use may be approximated, although less efficiently, through the use of a video cassette recorder interfaced with a microcomputer.

This particular configuration of equipment was chosen for the present research because it seemed to offer an effective way to present theory-based instructional modules in mathematics, while requiring little equipment beyond that generally available in schools. The research was designed to test the effects of this video/computer instruction on the attainment of the specific skills and concepts that the instructional materials were designed to teach, and to determine if the treatment would affect students' attributions of success and failure in mathematics, as contrasted with other academic subjects.

The development of the instructional modules was guided by task analysis (Gagne, 1977), which produced hypothesized hierarchies of skills and concepts for each topic, and by cognitive social learning theory, which served to identify classes of variables that have been found to influence observational learning (Bandura, 1977; Rosenthal & Zimmerman, 1978). The classes of variables selected for incorporation included attentional processes, retentional processes, and motivational processes.

Attention is essential to observational learning, and a number of studies have shown that discriminative attending is enhanced when a visual display directs attention to pertinent features of a task.

In addition, Rosenthal and Zimmerman (1978) have reviewed a number of studies demonstrating that affective cues influence both attention to visual displays,and willingness to perform the behaviors acquired through observation. Characteristics of the model are among those affective cues that appear to be relevant to attentional processes (Henderson & Bergan, 1976). Sex and social class (Maccoby & Wilson, 1957), age (Hicks, 1965), and ethnic status (Epstein) are among the model characteristics suggested by the literature as cues that influence attention. Accordingly, memorable and easily discriminated events and graphic images were judged to be important for incorporation into the video displays, and the models to be employed in demonstrations and dramatizations were selected to match the target audience on such dimensions as age, ethnicity, and manner of dress.

Modeled behavior must be represented symbolically by the observer if the witnessed information is to be retained (Rosenthal & Zimmerman, 1978). The provision of summary rule statements has been used successfully to accomplish this end in research in which modeling was used to teach abstract, rule governed behavior (Henderson & Swanson, 1978; Henderson, Swanson, & Zimmerman, 1975). Variables intended to influence attention were incorporated into the modules for the present research by supplementing the modeling of rule applications with frequent presentations of verbal and written (screen display) summary rule statements. Feedback and the opportunity for active responding have also been found, at least with young children, to facilitate the acquisition and retention of mathematical rules

(Swanson, Henderson & Williams, 1979). These variables were incorporated by giving students the opportunity to test their understanding of skills and concepts by actively responding to questions presented on the microcomputer. The problems posed in this fashion included both recognition and constructed response varieties. Feedback was provided by computer generated screen displays and by reviews of video material, controlled by the microcomputer.

Students who have experienced repeated failure on a given class of tasks may acquire a sense of helplessness in the face of future encounters with similar tasks. Those who manifest this pattern of "learned helplessness" are more likely than their more successful peers to attribute their failures to factors beyond their control (eg., low ability or bad luck), than to controllable factors, such as effort (Henderson, 1982). Some research (Zimmerman & Ringle, 1981) has demonstrated that children who view models expressing confidence in their ability and attributing their failures to lack of effort or persistence became more persistent and expressed increased self-efficacy. Such motivational variables were incorporated in the modules for the present study through the use of effort attribution statements by models on the video tapes, and by dramatized sequences in which modules demonstrated their ability to confront and overcome failure.

In summary, there is good reason to believe that instruction presented via an interactive system that unites the microcomputer's interactive characteristics with the unique capabilities of a video

cassette player to present demonstrations and dramatizations may provide a particularly effective means of teaching mathematical skills and concepts. The present study was designed to test the effects of theory-based instructional materials on skills identified by high school teachers as stumbling blocks for students with normal ability who had not made normal progress in mathematics learning. It was also hypothesized that students who were exposed to the materials would gain a sense of confidence in their ability to learn mathematics, and that they would attribute their performance more to effort than to ability or luck. No differences between the experimental and control groups in attributions relating to non-mathematical subjects were anticipated.

Field Trial 1

Methods

Subjects. The subjects for the field trial of the factors and prime numbers modules were selected from general mathematics and introduction to algebra classes in a high school serving a population that included a high proportion of hispanic students. School administrators made five classes available for a field trial of the modules and requested that pre- and posttests be administered to all classes at the same time, as a means of minimizing the disruption of classes. In order to distribute utilization of the computer/video equipment evenly across the available class periods, equal numbers of experimental students from each class were randomly assigned to the field trial participation group. Students from each class were

categorized on the basis of sex and ethnicity and assignment to the experimental condition was proportional to the number of students in each of these categories for each participating class. The original sample consisted of 43 control and 58 experimental students. Complete data on pre- and posttest results were available on a final sample of 36 control and 45 experimental students.

Procedures. All students in the classes that participated in the study were pretested on a criterion-referenced instrument to assess their knowledge and skills relating to factors and prime numbers. Students in the experimental group were told that people from the University had developed some new instructional materials in mathematics and that their help was needed to determine whether or not the materials were effective. Students were released from their regular mathematics class to participate in the modules. All students in the experimental group went through module #1 before any student began module #2, and participation in module #2 was completed before any student participated in module #3. The computer and video equipment was housed in a separate room in the library, where students could view the materials and interact with the microcomputer undisturbed. During the first half of the field trials, only one set of equipment was available, while a second setup later became available to speed up the treatment. Both sets of equipment were located in the same room and the students wore headsets for audio input. A female graduate student introduced students to the equipment and instructed them in the use of it for the first module. She sat unob-

trusively at the back of the room where she could observe the actions of the students as they participated in the modules, and where she could record their spontaneous verbalizations.

At the end of each session the students were asked in a casual manner to tell what they thought about the module they had just viewed. Each student who completed the factors module was asked the following three questions: 1) "So, how did you do?"; 2) "What did you think of all this?"; and 3) We would like to call you out again to go through more modules in the next few weeks. Would you like that?" The questions asked following the viewing of the Primes I and II modules were: 1) What did you think of this tape?"; 2) Do you want to continue?"; 3) "What did you think of all of the tapes?"; and 4) What did you think of learning from the computer? The research assistant recorded these reactions after the student left the room.

Approximately three months elapsed between the participation of the first student who used the modules and the completion of all modules by all the students in the experimental group. Approximately two weeks elapsed between the time when the first student to complete the modules finished module #3 and the completion of all of the modules by the last student in the experimental group. The posttest for factors and prime numbers was administered 2 days after the completion of all modules by the last student. There was, therefore, considerable variation among experimental subjects in the amount of time that elapsed between the completion of the computer/video instructional materials and the administration of the criterion

instrument. The students in both experimental and control groups were also given the School Learning Questionnaire, which was administered in a posttest only design because of time constraints imposed by scheduling considerations within the regular school program.

Instruments. A criterion-referenced test on factors and prime numbers was administered as a pre- and post-measure to students in both the experimental and control groups. Development of the instrument was guided by a systematic task analysis following Gagne (1977), resulting in a task hierarchy consisting of an hypothesized prerequisite ordering of relevant skills and concepts. Each task identified in the hierarchy was then translated into a set of task specifications (Hambleton & Eignor, 1979) in which the demand characteristics of the tasks were identified. Task specifications were then translated into test items.

A School Learning Questionnaire (SLQ) was developed to assess success and failure attributions with reference to both mathematics and non-mathematical subjects. Items were similar in structure to those used in the Intellectual Achievement Responsibility (IAR) Questionnaire (Crandall, Katkovsky & Crandall, 1965) except that a likert type response format was used rather then the dichotomized forced choice format employed in the IAR. For both failure and success, subscales consisting of 5 items each were created to measure attributions to ability (internal cause), effort (internal cause), chance (external cause), and task or situational factors (external cause). These factors, based on constructs originally postulated by Heider

(1958), have been hypothesized by a number of investigators (Henderson, 1982; Weiner, 1972, 1979), as variables affecting achievement motivation. The instrument yields 8 subscale scores (four for failure attributions and four for success attributions) pertaining to mathematics, and a parallel set of 8 subscale scores pertaining to non-mathematical school subjects.

Equipment. The configuration of instructional equipment included an Apple II Plus microcomputer interfaced with a videocassette recorder by means of firmware manufactured by BCD Associates. The lesson authoring software package provided by BCD was modified extensively to eliminate computer programmer jargon and to make it more user-friendly.

This configuration made it possible to present instructional input, and modeling sequences set in natural contexts (e.g. in classrooms, at home, with friends, on the telephone) by means of videotaped dramatizations. Video segments were followed by questions presented by the microcomputer. Both recognition (e.g., multiple choice) and constructed response (e.g., construct a factor tree) types of questions were used. Positive reinforcement was provided for correct responses and corrective feedback for incorrect responses was delivered by means of both printer messages provided by the microcomputer and by review of materials presented on videocassette. Relevant video sequences were called up by the microcomputer. High resolution graphics were generated on a PDP 11/70 computer, using the UNIX operating system.

Instructional Materials. The task hierarchy for factors and prime numbers served as a blue print for the development of the instructional modules. Story-boarding based on this hierarchy guided the first draft of the script for the videocassette portion of the modules. The first draft of the script was written by project mathematicians. The scripts were then edited for appropriateness of language level and to eliminate any content that could contribute to math anxiety or to the mystification of mathematics. Scripts were then reviewed by project psychologists who inserted modeling scenes designed to influence attentional processes, retentional processes, and motivational processes.

Variables inserted to influence attention included devices such as computer graphics with changing colors to focus attention on relevant stimuli, and the use of models whose personal characteristics (e.g. age, dress, ethnicity) were congruent with those of the target audience. Given the special concern that the materials be relevant to women and minority students but still useful to a more general audience within the target age group, the majority of the models presented on videocassette were female (3 out of 4), and of the female models, the majority (1 chicana and 1 black) were minorities.

Variables incorporated to influence retentional processes included 1) the use of memorable images associated with concepts and processes, 2) rule statements, presented by audio and screen print, to aid in the recall of critical attributes of the concepts

presented, 3) the opportunity to respond to questions driven by the microcomputer, and 4) the provision for corrective feedback. Feedback was provided in the form of positive reinforcement for correct responses, help statements printed on the screen for minor errors, and review of material from the videocassette for more serious mistakes. Where possible, video review material provided new exemplars of previously introduced concepts or processes, but production cost constraints necessitated the use of previously viewed material in many instances.

Variables that were incorporated to influence motivational processes included scenes demonstrating the use of mathematics in everyday life, and scenes depicting women engaged in occupations requiring the use of mathematics. Models were also shown making occasional errors, then overcoming their mistakes while verbalizing attributions to effort; e.g., "I wouldn't have made that error if I had been more careful," or "I can get it if I just stick with it."

Results. The criterion test for factors and prime numbers yielded three scores; a score for recognition responses, based on multiple choice and matching items, a constructed response score, based on items that required the production of a concept label or problem solution, and a total score based on the sum of the scores for recognition and constructed responses. The reliability of the factors/prime numbers test, as determined by the split half method and corrected for attenuation using the Spearman-Brown formula, was .96. Descriptive statistics for group performance on the test are

presented in Tables 1 and 2.

Insert Tables 1 and 2 about here

Recognition and constructed response scores were analyzed separately by means of 2 x 2 analyses of covariance for unequal N, following the method presented by Kerlinger & Pedhazur (1973). In each analysis, treatment groups (experimental and control) formed the first factor, with sex as the second factor. Ethnicity was not included as a separate factor because of substantial inequalities in sample size for minority and non-minority subjects. Adjustments for unequal N followed suggestions from Kerlinger (Personal communication).

The analysis of recognition response scores revealed significant main effects for groups $F(1,76) = 12.76$, $p < .0006$. The group x sex interaction was not significant. An adjusted mean analysis (Kerlinger & Pedhazur, 1973) was applied to the post test scores. The unweighted means analysis revealed that the control group gained 5.98 fewer points than the experimental group. This approximates a 1 standard deviation difference, a large effect size according to Cohn (1969). An effect of this size can be interpreted as a 38% improvement in success rate, on the basis of the binomial effect size display advocated by Rosenthal and Rubin (1982) as a means of communicating magnitude of effect.

The adjusted means for each sex were tested for treatment group differences, using the a priori t test for unequal n's (Kerlinger & Pedhazur, 1973). Male and female experimental subjects both exhibited greater gains than their control group counterparts (p's < .02 and .002, respectively). The ANCOVA for the constructed responses showed a significant main effect for the treatment groups, F (1,76) = 11.26, $p < .001$. No other terms were significant. The unweighted means analysis showed that the experimental group surpassed the gains made by controls by 7.36 points. The difference of slightly more than 1 standard deviation qualifies as a large effect (Cohn, 1976), indicating a 36% improvement in success rate, as determined by the binomial effect size display (Rosenthal & Rubin, 1982). The ANCOVA summary is presented in table 4. The post hoc comparisons revealed that male experimental subjects made significantly larger gains than control males ($p < .2004$), and that experimental girls also made greater gains than their control group counterparts ($p < .0027$).

Insert table 4 about here

Data from the School Learning Questionnaire (SLQ), administered following the intervention, were available for 73 subjects, 42 experimentals and 31 controls. The data were analyzed in a 2 x 8 ANOVA, in in which treatment group constituted the between subjects factor and the within subjects factor was formed by the eight subscales of the SLQ form for mathematics. The main effects for groups was not significant F (1,71) = 1.289, ns, thus failing to support the expectation

that the experimental group would surpass the controls in the attribution of outcomes to effort. A second 2 (treatment groups) x 8 (subscale) ANOVA performed on the non-mathematics form of the SLQ revealed a very similar pattern. The main effect for groups was not significant, F (1,71) = 1.059, ns. Descriptive statistics for both forms of the scale are presented in Table 5. Inspection of the means for the subscales shows a very similar pattern of means for comparable subscales on the mathematics and non-mathematics forms.

Insert Table 5 about here

When asked how they did on the factors module, most students responded by relating the score reported by the computer. Typical responses were "I got 80%."; "I got 100%."; "Oh, okay."; "Not very good. Only 52."; "Wow! I got 100%."; "I just missed one and I knew what I did wrong right away." Typical responses to the open ended question asking what students thought about the approach were: "I did good. It was easy."; "It's hot man. This thing could really help."; "I really liked it. It was fun."; "Yes, it's weird what they can do with computer these days."; "I love it."; "Well, my dad was going to

buy us one of these and he didn't. But now I'm gonna ask him to. It's good."

When asked if they would like to participate in additional modules, students were almost unanimous in giving a positive response.

Student responses to the two modules on prime numbers are represented by the following typical comments: "I got 84%. It was fun."; "I didn't do too well, 55%, but I still liked it."; "One hundred percent. It's good."; "I got 76%. Is that OK?"; "It's better than coming to class. I'd like to come back."; "I'm a dummy. I didn't make it through the tape. I guess I was never cut out to be smart. I did learn what factors and primes are though."; "I really liked this one. It's fun."; "Can I do the next one?"; "Can I come in next period? Lunch?"

After the final module, students made comments such as the following: "I liked it even though I had trouble with it. I learned about factors and multiples and I never learned them in class. I liked the computer. In a way,I think you can learn just as much or more from a computer because its just you, while in the class, the teacher has to go on and pay attention to the other students. But in a way, I'm glad it's over with. The headphones bothered me. There was a high-pitched noise which hurt my ears and they were uncomfortable."; "It was fun. I liked learning from the computer so you didn't have to have the teacher help you."; "Its better than class."

Finally, when the students were asked, "What did you think of the module?," of the forty-two people who responded to the module on factors: 32 (76%) responded positively, 9 (22%) were neutral, and 1 (2%) was negative. For the same question for the Primes I module, of the forty-two responding: 19 (69%) were positive, 11 (26%) were neutral, and 2 (5%) were negative. When asked the same question for the Primes II module, 45 students responded in the following way: 36 of them (80%) were positive, 8 (18%) were neutral, and one (2%) was negative.

Field Trial 2

The second field trial was conducted to provide a mini-replication of the initial field test of the factors and prime numbers modules, and a pilot test of the fractions modules. It was not possible to use a control group to guard against threats to internal validity in this test of the materials, but this trial did make it possible to examine the potential utility of such materials in a remedial education setting.

Subjects. The subjects for this field trial were volunteers from an alternative school special summer program for students who had failed to pass the basic skills competency test required for high school graduation. Their regular school class placement ranged from tenth through twelfth grade. A total of eleven students, 9 boys and 2 girls, participated in the use of the modules for factors and prime numbers and for fractions. Complete pre- and posttest results for both instructional packages were available for 8 males and 1 female.

Materials and Procedures. The instructional materials and field trial procedures for this test of the factors and prime numbers modules were identical, except for location and research assistants, to those employed during field trial 1. The fractions package consisted of 6 modules developed to teach concepts and operations involving fractions. The production procedures for these modules were identical to those previously described for factors and prime numbers. The equipment configuration and field trial procedures were also the same as those employed in the field testing of the factors and prime numbers modules.

The criterion test for factors and prime numbers was administered to the entire group prior to their viewing of the modules. The posttest was administered after all students had viewed the three modules that constituted the factors and prime numbers package. All students were then pretested with a criterion referenced instrument developed to assess attainment of the objectives that were incorporated in the six modules of the fractions series. The posttest was administered upon completion of all six modules by the eight students for whom complete data were available.

Results. Repeated measures analyses of variance were applied to field trial data for the remedial summer school students' performance on the recognition and constructed response items of the factors and prime numbers criterion measure. The analysis of criterion response scores revealed a significant main effect for trials, F (1,20) = 10.99, $p < .007$, indicating a significant change in recognition

response performance from pretest (mean = 14.45) to posttest (mean = 23.64). The analysis of constructed response measures for factors and prime numbers also identified a significant main effect for trials, F (1,20) = 22.53, $p < .001$. The mean at the time of pretesting was 11.18, while the posttest mean was 21.09.

Repeated measures analyses of variance were also employed to assess the difference between pre- and posttest recognition and constructed response scores for the criterion test for the fractions modules. The main effects for trials were significant for both recognition, F (1,14) = 8.75, $p < .02$, and constructed responses, F (1,14) = 6.10, $p < .04$.

Discussion

The results of the field trials show quite clearly that the computer-video instructional modules were effective in teaching or reteaching mathematical skills and concepts to secondary school students who had not made normal progress in mathematical learning. In the first field test, students who used the materials gained a statistically and practically significant advantage over controls in skills and concepts involving factors and prime numbers. The pattern of gains attributable to these modules was replicated in the second field trial, but without a control group as a safeguard to internal validity. Comparable effects were also found to be associated with

the use of modules for fractions, but these results should be interpreted with caution because there was no control group. The grant providing funding for this work called for and supported only limited field testing, and more extensive testing of the fractions modules, with appropriate control conditions, is needed.

The hypothesis that exposure to the materials would help students to recognize that it is possible for them to learn mathematics, and that this would be reflected, in part, in an increase in effort attributions specific to mathematics, was not supported. Although observational information and data from the informal exit interviews show that students felt that they had learned from the experience, and that they felt very positive about it, these feelings were not reflected in data from the School Learning Questionnaire. This could be a result of the failure of a relative brief period of successful experience to overcome beliefs acquired over a long period of time. It should be noted, however, that experimental and control subjects alike attributed both failure and success experiences in mathematics more to effort than to other causes. Thus, it is possible that the data reflect a ceiling effect, and that the instrument was not sufficiently sensitive to detect any change that might have occurred.

The materials tested in the field trials reported here were not designed as a substitute for regular classroom instruction. They were intended as a test of the feasibility of employing computer-video technology to assist students who had failed in the past to master important mathematical competencies. The goals and objectives

of the materials were predetermined by the researchers, as were the instructional sequences. Some open-ended exploratory seqments (e.g., a factor tree episode in which students could use trial and error) were included in the modules, but, in general, these were not discovery based materials. A minority of educators who have viewed the materials have expressed the view that the the use of computers for instructional purposes should be limited to approaches in which the learner is given greater control and opportunities for discovery. We would be among the first to acknowledge the importance of discovery oriented materials of excellent quality, such as LOGO. At the same time, we believe there is a serious shortage of validated materials of the kind reported here. These materials go well beyond the moving books and drill and practice exercises that constitute the majority of current instructional applications of computers (Bonham, 1983). These materials combine the major unique features that some learning theorists suggest should optimize the liklihood of learning and retention. Future applications hold the promise of making it possible to "contextualize" (Zimmerman, 1983) learning in subjects such as pre calculus. It seems important that support be provided for the continued development of instructional materials that build on the significant advances being made in research on learning and cognition, and for the validation of promising materials that take advantage of the unique potential of new technologies. The importance of theoretically guided research and product validation cannot be over emphasized, since, as George W. Bohnam (1983) has noted so cogently, much of the shape of the future in technology based

education is being determined by profit-oriented textbook publishers and equipment manufacturers.

When suggestions from research are pulled together to guide the development of materials, particularly those designed for delivery via educational technology, one cannot predict, nor does field testing reveal, how the several incorporated variables work in combination with one another. What is needed is a dynamic interaction among basic research in learning and cognition, the development and validation of products based on theory and basic research, and applied research designed to assess the respective contributions of product elements and their interactions. Research of an immediate nature is needed to compare the effects of microcomputer and video based instruction in isolation, and in combination with one another. Investigations are also needed to examine the efficacy of the materials used in the present work when used with students who differ in age, or in educational status (e.g., who may be introduced to a topic via these materials and those who failed to acquire the competence through regular classroom instruction). Some media research (Henderson & Swanson, 1978) has suggested crucial interactions among the nature of the concept presented the age of the learners, and the conditions required for learning to occur.

Finally, serious thought must be given to the place of emerging technologies in the education of the immediate and long range future. There has been little of the comprehensive planning and vision that are necessary to guide a thoughtful and effective, rather than disor-

ganized and fragmentary, application of new instructional technologies. Bohnam (1983) has rightly commented that "there has been little critical analysis of the educational significance of what is being done" (p. 72). An assessment of the potential of developments such as those reported here, to say nothing of computer literacy, discovery oriented learning, and other applications that may compete for time and resources, should ultimately be judged within such a comprehensive view. It is clear, however, that effectiveness data, such as those reported here, form a necessary part of any comprehensive planning.

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Table 1

DESCRIPTIVE STATISTICS:
RECOGNITION RESPONSES FOR
FACTORS AND PRIME NUMBERS MODULES

		Pretest		Posttest	
	N	Mean	SD	Mean	SD
Experimental Males	23	16.35	6.24	23.26	6.26
Experimental Females	22	20.18	6.85	25.86	6.24
Experimental (All)	45	18.26	6.82	24.56	6.37
Control Males	22	18.27	6.96	19.14	7.54
Control Females	14	17.29	5.28	16.57	4.72
Control (All)	36	17.76	6.38	18.21	6.70

Table 2

DESCRIPTIVE STATISTICS:
CONSTRUCTED RESPONSES FOR
FACTORS AND PRIME NUMBERS MODULES

		Pretest		Posttest	
Group	N	Mean	SD	Mean	SD
Experimental Males	23	15.87	6.85	25.70	5.92
Experimental Females	22	17.36	8.59	24.82	7.07
Experimental (All)	45	16.62	7.91	25.26	6.52
Control Males	22	15.14	6.85	17.14	8.69
Control Females	14	14.93	6.53	16.07	7.40
Control (All)	36	15.03	6.72	16.60	8.23

Table 3

SUMMARY FOR ANALYSIS OF COVARIANCE
FOR FACTORS AND PRIME NUMBERS MODULES FIELD TEST:
EFFECTS FOR GROUPS AND SEX ACROSS
RECOGNITION RESPONSE TRIALS

Source	df	Variance Explained	F	p
Covariate (Pretest)	1	.1570	-	
Treatment (A)	1	.11151	12.764	<.0006
Sex	1	.0044	.50	-
Interaction	1	.0073	.84	-
Error	76	.66366		

Adjusted Means on Posttest

	Male	n	Female	n	Total
Experimental	23.9423	23	25.0256	22	24.47
Control	19.06	22	17.60	14	18.49

Table 4

SUMMARY FOR ANALYSIS OF COVARIANCE
FOR FACTORS AND PRIME NUMBERS MODULES FIELD TEST:
EFFECTS FOR GROUPS AND SEX ACROSS
CONSTRUCTED RESPONSE TRIALS

Source	df	Variance Explained	F	p
Covariate (Pretest)	1	.2291		
Treatment	1	.0824	11.29	.0012
Sex	1	.0014	.1863	
Interaction	1	.0004	.0644	
Error	76	.5585		

Adjusted Means on Posttest

	Male	n	Female	n	Total
Experimental	25.73	23	24.10	22	24.93
Control	17.53	22	16.56	14	17.57

Table 5

MEANS AND STANDARD DEVIATIONS
FOR SCHOOL LEARNING QUESTIONNAIRE:
MATHEMATICS AND NON-MATHEMATICS FORMS

Gp	SIA	SIE	SEL	SET	FIA	FIE	FEL	FET
				Mathematics				
Exp	13.17	15.12	10.81	11.68	10.48	14.17	10.10	11.93
	(2.01)	(2.48)	(2.00)	(1.87)	(2.369	(2.28)	(2.26)	(2.62)
Con	12.97	14.74	10.87	11.59	10.55	12.77	9.77	11.32
	(2.32)	(2.70)	(2.37)	(2.52)	(3.16)	(2.04)	(2.87)	(1.99)
				Non-Mathematics				
Exp	12.71	14.31	11.02	12.31	11.12	14.45	10.31	12.31
	(1.97)	(2.37)	(2.56)	(1.80)	(2.47)	(2.75)	(2.40)	(2.17)
Con	12.61	15.81	10.74	11.65	9.61	15.26	9.16	11.87
	(2.30)	(3.08)	(2.67)	(1.98)	(2.58)	(2.97)	(2.96)	(2.59)

Figures in parentheses designate standard deviations.

SIA = success, internal, ability
SIE = success, internal, effort
SEL = success, external, luck (chance)
SET = success, external, task (situation)
FIA = failure, internal, ability
FIE = failure, internal, effort
FEL = failure, external, luck (chance)
FET = failure, external, task (situation)